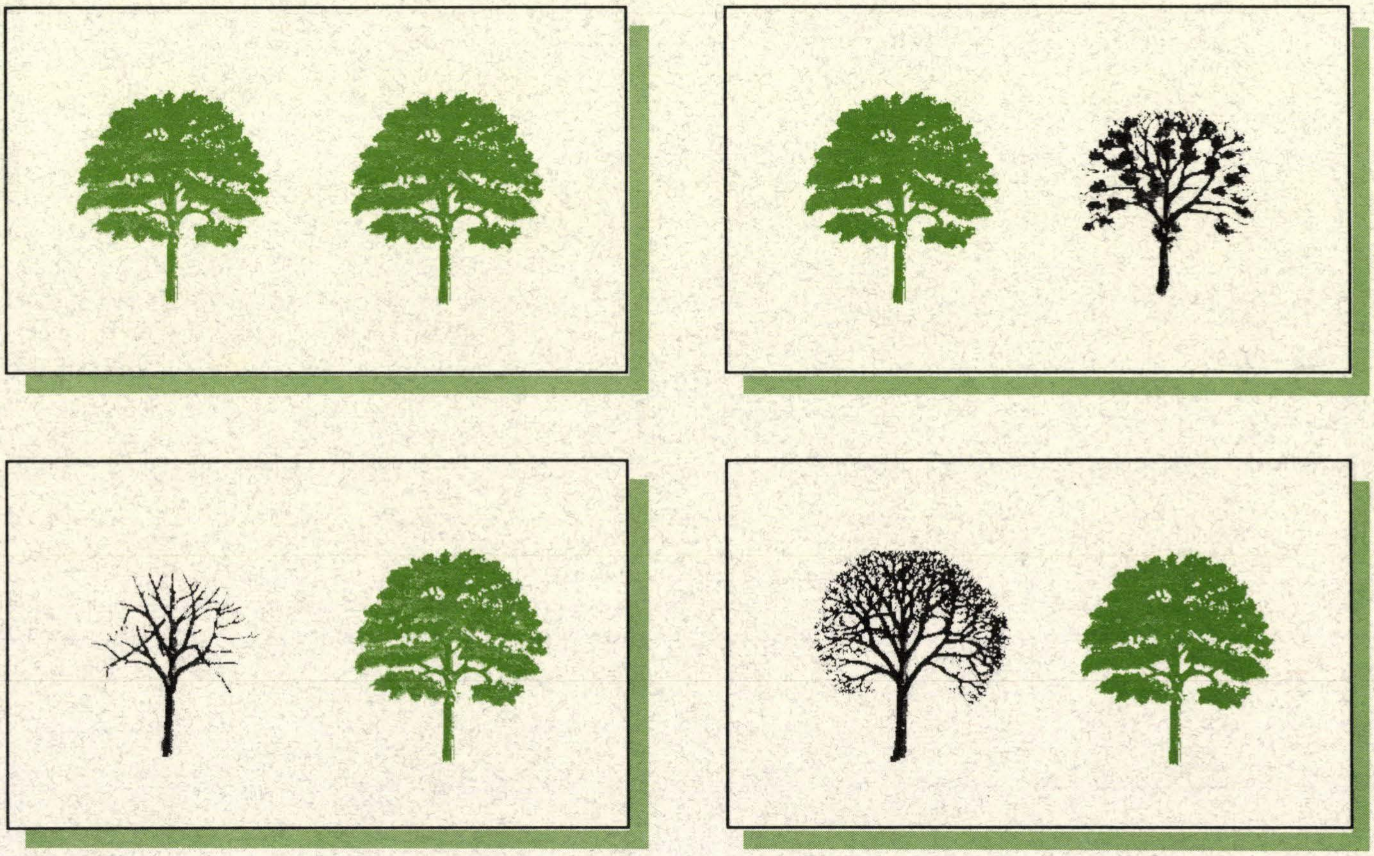
VERMONT HARDWOOD TREE HEALTH IN 1991 COMPARED TO 1986



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ABSTRACT

Based on interpretation of aerial photos and ground measurements, a statewide hardwood tree health survey was conducted in 1985-86 and repeated in 1990-91. The latest survey shows that overall, our hardwood forests are in good condition, with definite improvement since 1985. Over thirteen thousand acres were estimated to have moderate to heavy mortality (more than 10% of the canopy trees dead) based on 1985 photos, but this dropped to less than four thousand acres in 1990. Tree health, based on ground evaluations, also improved during the five years. Nearly 86% of all trees in upper canopy positions were healthy (0-10% crown dieback) in 1991 compared to 78% in 1986. Percentage of dominant/codominant trees dead increased from 2.9% in 1986 to 5.5% in 1991, but those with moderate to severe dieback (11-100%) dropped from 19.3% in 1986 to 9.1% in 1991. The majority of trees with moderate dieback (11-50%) in 1986 recovered to a healthy crown condition by 1991. Sugar maple showed the best ability to recover following severe dieback. Improvements in crown condition may be related to decreased insect damage and recent years with above average precipitation.❑

INTRODUCTION

In 1990 and 1991, a survey was conducted by the Vermont Department of Forests, Parks and Recreation to determine the current health status of Vermont's hardwood forests. This was a repeat of a 1985-86 survey that established a data base for future monitoring of tree condition and the effects of various stresses on all species of trees in Vemont hardwood stands. Both surveys were a cooperative effort with the U.S.D.A. Forest Service, Forest Pest Management Methods Application Group in Fort Collins, Colorado and Forest Health Protection Staff in Durham, New Hampshire.

The Fort Collins staff acquired the aerial photographs and provided technical assistance in project planning, photo interpretation and data analysis. The Durham staff provided technical assistance, ground surveyed the selected photo points that fell on federal land, and interpreted the 1990 aerial photography for the resurvey. The State did the photo interpretation for the initial survey in 1985, developed the ground survey procedures, surveyed selected photo points on state and private land, and was responsible for reporting the results and conclusions.

The specific objectives of each survey were to:

- Determine number and volume of dead and declining hardwood trees per acre;
- Determine the area of hardwood decline and mortality by mortality class;
- Provide data on tree mortality, crown condition, site and stand factors to be used to determine trends in tree condition over time.

The initial survey followed a period between 1977 and 1982 when over one-fourth of Vermont's northern hardwoods (about 498,000 acres) were defoliated at least once by the forest tent caterpillar (*Malacosoma disstria*). This resulted in 33,000 acres of tree crown dieback and tree mortality. Thousands of additional acres were defoliated by outbreaks of gypsy moth (*Lymantria dispar*), maple leafcutter (*Paraclemensa acerifoliella*), and saddled prominent (*Heterocampa quttivata*), as well as by late-spring frosts in 1980 and 1986 (Appendix A). Additional stress factors during this period included below average precipitation and a cold, open (little snow cover) winter in 1980-81. This abundance of natural stress factors occurred when there was much public concern about the impacts of pollutants on tree health.❑

METHODS

SURVEY DESIGN

A two-stage sampling design was used for both the initial 1985-86 survey and the 1990-91 resurvey. First, aerial photos were used to get a broad view of tree dieback and mortality and to serve as a basis for selection of ground plots. Then the ground survey was used to take a closer look at the extent of dieback and mortality. The average numbers and volumes of trees in each of the crown condition classes computed from ground data were expanded into estimates of totals and per-acre means for the entire state.❑

AERIAL PHOTOGRAPHY

The first stage units were 360-acre aerial photo blocks. Color infrared photography of these blocks at a nominal scale of 1:8000 was obtained between late August and mid-September 1985 and again in August, 1990. One-hundred-seventy photo points were systematically established over the entire state in 1985 on flight lines 7.4 miles apart, at 7.4 mile intervals (Figure 1). Five consecutive 9" x 9" transparencies with 70% forward overlap were taken at each point by a Zeiss RMK 21/23, nine inch aerial camera. Kodak aerochrome color Infrared film (Type 2443) was used in combination with a Wratten 12 (minus blue) filter.

The first flight line and the first photo point on each flight line in 1985 was based on a random start.

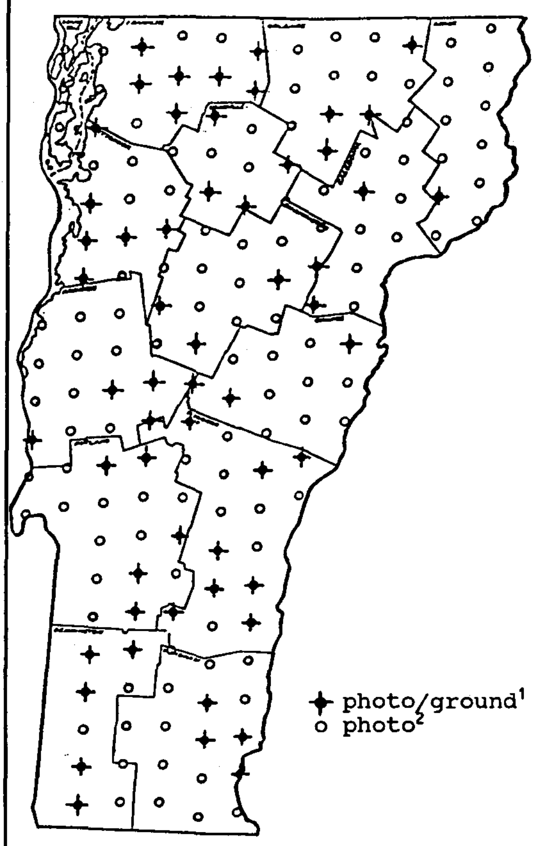

Figure 1. Sample point distribution in the Vermont Hardwood Tree Health Survey.

1. Photo points photo-interpreted and ground surveyed
2. Photo points photo-interpreted only.

In 1990, a Loran C navigational system and color aerial prints of the 1985 blocks were used in the airplane to help locate the same points for new photography. Information obtained through photo interpretation of these blocks was used to estimate the acreage of land in each of the vegetation/damage classes in the photo interpretation section to follow.❑

PHOTO INTERPRETATION

Each aerial photo block was divided into 144 cells (secondary sampling units) that were each 2.5 acres in size. The center photo from each point was selected for interpretation using the two adjacent photos for stereo viewing. Actual photo scale ranged from about 1:7000 to 1:9000. Clear plastic overlays consisting of 144 cells on a 12 x 12 grid were constructed for each 500 scale increment in 1985 and each 100 scale increment in 1990 (to more easily match the original grids). The overlay closest to average scale for each center photo was used to examine a 360-acre block using an Old Delft scanning stereoscope, Bosch and Lomb Zoom 240, or other high quality stereoscope. Since some cells interpreted in 1985 were missed with the 1990 photography, comparative data for 1985 was adjusted to reflect those cells common to both years.❑

Each 2.5 acre grid cell was examined in stereo and classified into one of the following vegetation types and hardwood mortality classes.

1. Vegetation Type

A. Hardwood - all cells where 50 percent or more of the cell area is forested and where 75 percent or more of this forest canopy is hardwoods.

B. Other Forest[1] - all forested cells where 50 percent or more of the cell does not meet the criteria for A. This includes mixed wood or conifer forests.

C. Non-Forest[1] - All cells where 50 percent or more of the cell area is not forested. Includes agricultural areas, lakes, ponds, urban areas, etc.

D. Cloud Cover - all cells where one-half or more of the cell is obscured by clouds.

E. Inundated - all cells which meet the above criteria but the forested area is flooded by water.

2. Size Class

In 1985, stands were identified as either poletimber or sawtimber. Stands were not separated by size class in 1990. This interpretation proved to be less repeatable than mortality class information and combining them simplified analysis and reporting.

3. Mortality Class

Photo cells were examined under stereo and the number of recently dead hardwood trees counted (excluding snags[2]) to determine the following mortality classes:

A. Light[3] - less than 10 percent of the hardwood canopy trees dead.

B. Moderate - 10 to 30 percent of the hardwood canopy trees dead.

[1]In 1985, "Other Forest" and "Non-Forest" were combined into one category called "Other".

[2]Snags - Dead trees with only a main stem or 1 - 2 lateral branches remaining.

[3]In 1990, cells in the light mortality stratum were further divided into four classes based on 0, 1, 2-4 or more than 5 dead trees per cell. Analysis was limited to the one broad class to compare to 1985.

GROUND SURVEY

Ground survey was conducted to take a closer look at the extent of dieback and mortality. Based on interpretation of 1985 photos, all of the heavy mortality cells, 50 percent of the moderate mortality cells, and 5 percent of the light mortality cells were randomly selected for ground survey. This resulted in 2, 22, and 51 cells, respectively, for a total of 75 cells. Five 10-factor prism points were established in each 2.5 acre cell and site and tree data were collected in 1986 and again from the same points in 1991.

Site Data

At each prism point, the following site data was taken: elevation, percent slope, slope, aspect in degrees azimuth, stand geography (hillside, rolling, swamp, mountain top, plateau, cove, plot, bench), drainage (poor, well, excessive), crown closure (<25%, 25-74%, >75%), and logging activity evidence (none, recent-slash present, recent-stumps only, old-stumps). Rock outcrops and roads were recorded as present or absent within each plot. This information was collected within a circular area with a radius from plot center to the bole of the furthest tree within the prism plot.

Defoliation history since 1975 was recorded for each cell by recording the insect or agent responsible as determined from department aerial survey records.

In each cell, two healthy hardwood trees in dominant or codominant canopy positions were cored and height measured with a clinometer to determine site index information. Regeneration data for trees less than one inch dbh was taken from five milacre plots at each prism point. In addition, plant species that are indicators of good, wet, or poor sites were recorded as present if within 20 feet of plot center for each prism point.

In 1986, soil depth information was collected and soil samples were collected and analyzed for pH, nutrients and heavy metals. This was not repeated in 1991.

Tree Data

In 1986 all trees greater than one inch diameter at breast height (dbh) that fell into each prism point were numbered with paint and tallied for tree data (ground survey data form, Appendix B). Ingrowth trees were added in 1991. Over 2,000 trees in dominant or codominant (upper canopy) crown positions were tallied. Sugar maple, red maple and yellow birch were the species most frequently evaluated (Figure 2).

General tree data collected included information on: species, dbh to the nearest inch, crown class (dominant, co-dominant, intermediate, over-topped), sawlog height to the nearest eight feet, cordwood height to the nearest four feet, and crown condition. Tree heights were measured in 1986 only, because change in volume of hardwoods due to increased height growth in 5 years was not expected to be very significant and any gain might be offset by variation in remeasurement estimates. Snags were excluded from volume estimates. ❑

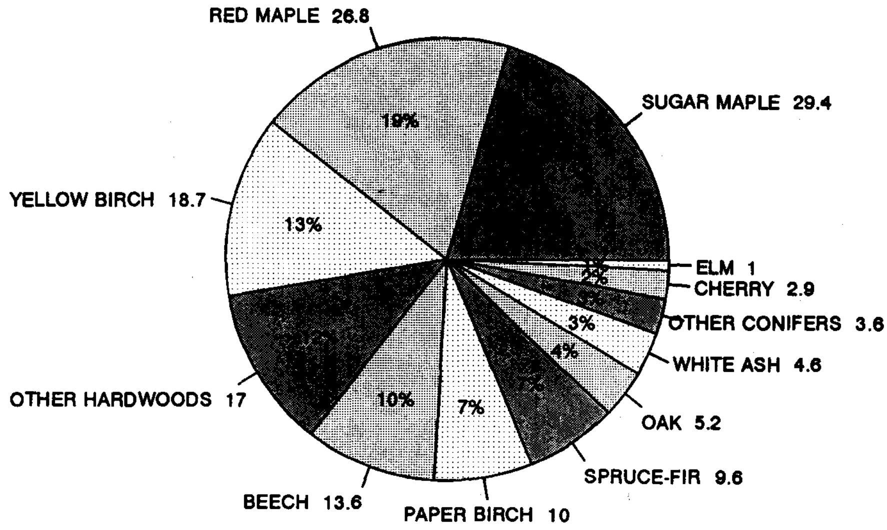

Figure 2. Average number of upper Canopy position (dominant/codominant) trees per acre, by species (1991 ground survey).

1. Crown Condition Data

Crown condition evaluations included ratings for branch dieback, crown transparency, and crown symptoms and injuries. Dieback was based on visual estimates of the portion of tree crowns represented by twigs and branches that had recently died from the tips back.

In 1991, 5 percent crown dieback categories were used to coincide with national standards developed by the National Forest Health Monitoring Program. These were combined into broader categories during analysis to compare with the following 1986 categories:

Crown Dieback Ratings	Crown Dieback (Percent) 1986	1991
· Healthy	0 1-10	0 1-5, 6-10
· Moderate Dieback	11-25 26-50	11-15, 16-20, 21-25 26-30, 31-35, 36-40, 41-45, 46-50
· Heavy Dieback	51-75 75-99	51-55, 56-60, 61-65, 66-70, 71-75 76-80, 81-85, 86-90, 91-95, 96-99

· Dead (1986 and 1991)
Recently dead - fine branches present
Older dead - no fine branches and more than two lateral branches present
Snag - only the mainstem and two or fewer lateral branches remaining.

All crown dieback and transparency estimates were made by two observers on opposite sides of each tree. Crown ratings for 7 percent of the ground points were remeasured by different observers to assess measurement variability.

2. Crown Transparency

In 1991, crown transparency ratings were taken for the first time, again to correspond with national standards. Transparency is the amount of skylight visible through the foliated portion of the crown and was estimated in the same 5% classes as used for dieback ratings.

3. Symptoms and Injuries

Up to five crown symptoms and injury-causing agents were recorded for each tree, if present (Kelley and Eav 1987).❑

DATA ANALYSIS

Simple random sampling formulas were used to estimate the area in each vegetation/mortality class and the standard error of each estimate (Cochran 1977). It was assumed that there is no definite pattern in the unit values of acreages of each class in the population.

To compute estimates of the number and volume of trees in each crown condition class, the mean values and variances of the means were computed from ground cell means for each vegetation/mortality class in the hardwood type. The estimates of total values for each class is the product of the estimates of the mean values with the estimates of acreage for the class. The formula for computing standard errors of the estimates is given by Freese (1962).

The combined statewide estimates were computed by the stratified random sampling (with relative stratum size) approximation formulae (Freese 1962). Per-acre averages are weighted averages based on acres in the three mortality classes

Crown condition classes for individual tree species were combined into generic groups for oaks, spruce, and pines, although the predominant species within each group were northern red oak, red spruce, and white pine, respectively. Snags were excluded from data analysis. All 1991 volume calculations are based on tree heights obtained in 1986, and 1986 diameters were used for some of the dead trees where 1991 diameters were not obtained. Thus, volume estimates, particularly for dead trees, should be a slight underestimate of true volume. Boardfoot and cordwood volumes for dead and severely declining trees were computed from International one-quarter inch rule formulas by Gevorkiantz (Beers and Miller 1966).

Cubic-foot volume was computed from the cordwood formula modified to include tops to a two-inch branch diameter. Moderate and heavy mortality classes were combined during data analysis because of little heavy mortality in 1986 and none in 1991, as estimated by photo interpretation. Data for 1991 were recalculated to reflect this combining of the two size classes and to adjust for the loss of two ground cells.❑

PHOTO INTERPRETATION RESULTS AND DISCUSSION

HARDWOOD AREA

The total area of forest classes estimated from systematic samples of 1990 color infrared photographs was similar to estimates obtained with 1985 photography. The area of hardwood in Vermont was estimated at 2.69 million acres in 1991 compared to 2.51 million acres in 1985.

Another 1.88 million acres were classified as non-hardwood forests and 1.58 million acres were classified as non-forested. This generally agrees with the 2.8 million acres of hardwood types estimated in the 1983 Forest Survey of Vermont (Frieswyk and Malley 1985).❑

AREA OF MORTALITY

The area of moderate or heavy tree mortality based on interpretation of aerial photographs decreased nearly 70 percent from over 13,000 acres in 1985 compared to less than 4,000 acres in 1990 (Table 1). This represents 0.1 percent of Vermont's hardwood type compared to 0.5 percent in 1985. This result is similar to that of a 1987 survey of Maine's Miller 1966).

Cubic-foot volume was computed from the cordwood formula modified to include tops to a two-inch branch diameter. Moderate and heavy mortality classes were combined during data analysis because of little heavy mortality in 1986 and none in 1991, as estimated by photo interpretation. Data for 1991 was recalculated to reflect this combining of the two size classes and to adjust for the loss of two ground cells.❑

Table 1. Area of hardwood type in Vermont within each mortality class estimated from 1990 photo interpretation, and change from 1985.

Mortality Class1	**1990 Acres**	**Std. Error**	**Change From 1985**
Light	2,689,451	142,775	+169,757
Moderate	3,857	1,544	- 9,133
Heavy	0	0	527

1. Light = less than 10 percent of hardwood canopy trees dead.
Moderate = 10 to 30 percent of hardwood canopy trees dead.
Heavy = more than 30 percent of hardwood canopy trees dead.

GENERAL TREE CONDITION

The percentage of trees in dominant or codominant crown positions rated as healthy, increased from 77.8 percent to 1986 to 85.6 percent in 1991 (Figure 3). Percent of trees dead increased from 2.9 percent in 1986 to 5.5 percent in 1991, but the percentage of trees with moderate or severe dieback dropped sharply (19.3 to 9.0). The same trend was evident for trees of all sizes (Appendix C).

This survey uses a fairly conservative definition of "healthy" meaning up to 10 percent crown dieback based on ground evaluations.

A 1987-1988 Wisconsin survey to evaluate the health of sugar maple and other northern hardwoods considered trees with crown dieback up to 20 percent to be healthy (Mielke et al. 1991). The Wisconsin survey reported that 92.7 percent of all trees over 5 inches d.b.h. in northern hardwood stands were healthy in 1988. The National Forest Health Monitoring Program begins their moderate dieback category at 21 percent (Brooks et al. 1991). The North American Sugar Maple Decline Project considers trees with crown dieback up to 15 percent to be healthy (Millers et al. 1992).❑

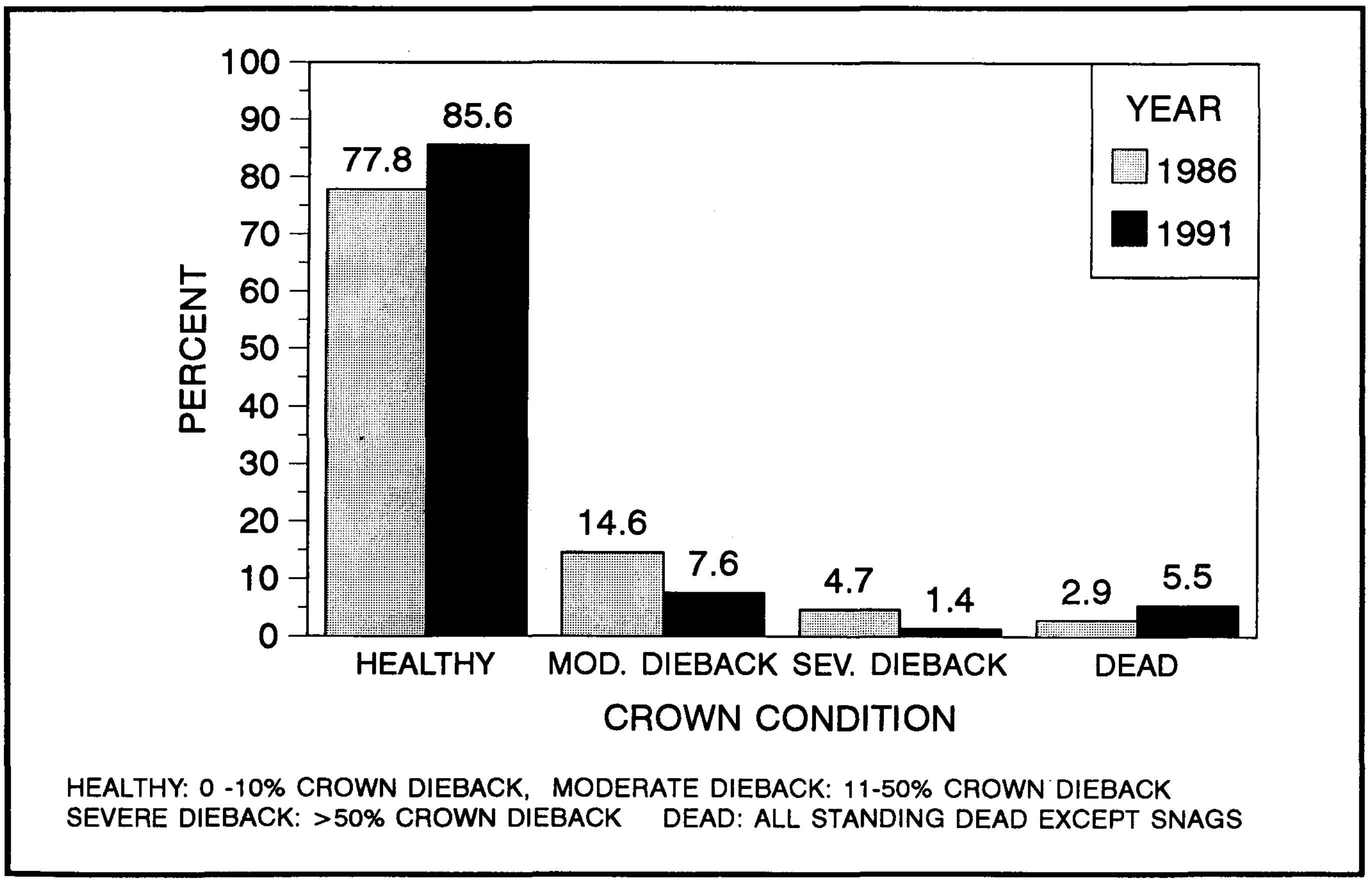

Figure 3. Crown dieback ratings of dominant/codominant trees in Vermont hardwood stands in 1991 compared to 1986.

The increase in dead trees is due to a progression of dieback on some trees, probably as a result of stress factors in the early 1980's. This is particularly true of trees with severe dieback (over 50%) in 1986, since 53 percent of these trees were dead in 1991 (Figure 4). Of the trees in this category that didn't die, more than half had recovered to a healthy crown condition by 1991.

Number and volume of standing dead trees (excluding snags) increased between 1986 and 1991 regardless of crown position (Table 2). Number of dead dominant/codominant rees dead increased from 3.8 per acre (15 cu.ft.) in 1986 to 7.1 per acre (77 cu.ft.) in 1991.

This increase in dead trees by number of trees per acre parallels the increase on a percentage basis shown in Figure 3. Volume comparisons for all trees and dead trees are listed in Tables 4, 5, and 6 of Appendix D.

Trees that had died since 1986 had stem rot and breakage due to ice and snow damage as the first and second most frequently recorded injury or causal agents, respectively. Most of the ice and snow damage probably resulted from the October 1987 and November 1990 snow storms (Appendix A). ❑

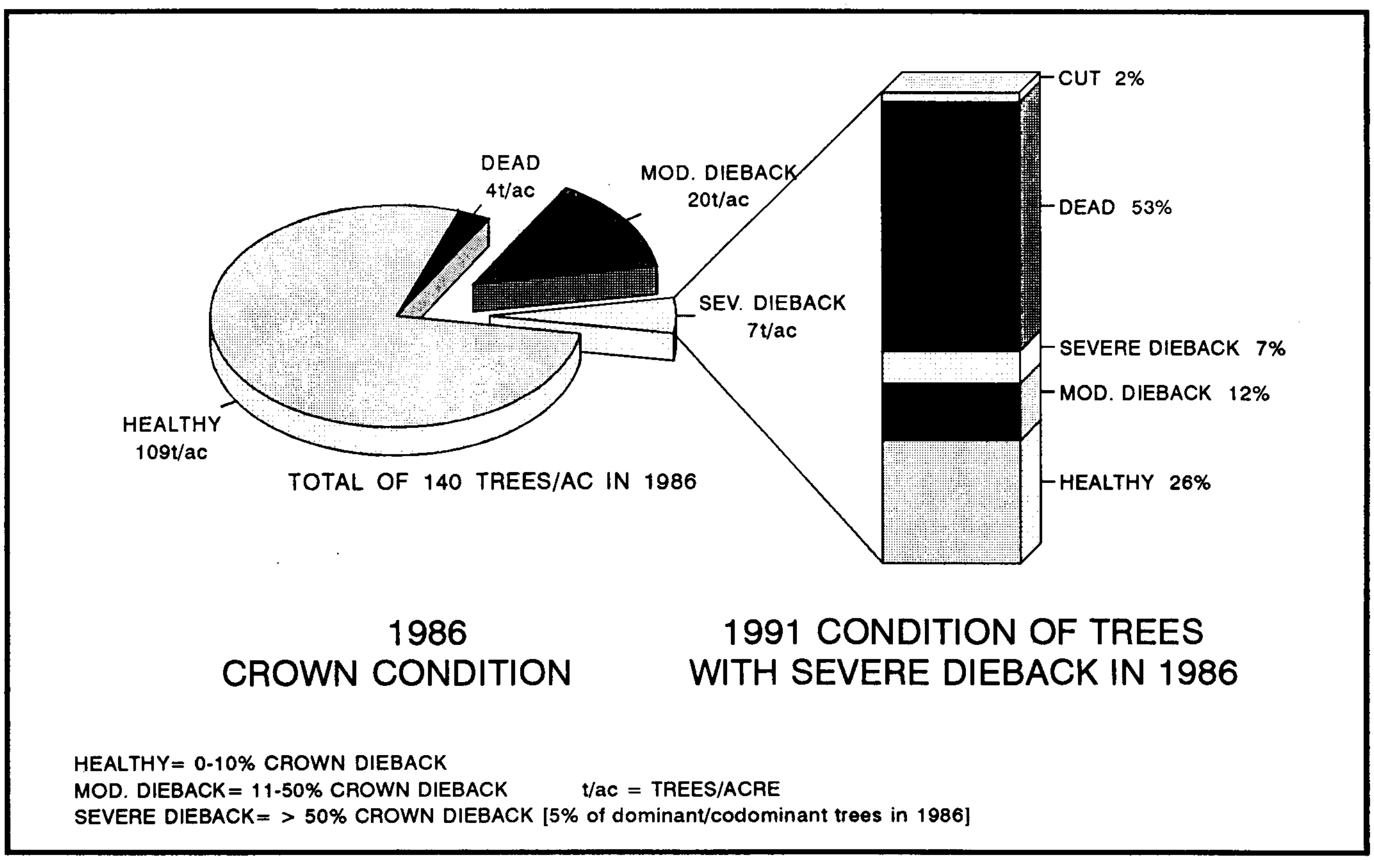

Figure 4. 1991 condition of all dominant/codominant trees with severe dieback in 1986.

Table 2. **Average number and volume per acre of ground surveyed standing dead trees (excluding snags) by photo interpretation mortality classes in Vermont hardwood stands - 1986 and 1991.**

Photo Interp. Mortality Class	1986 Dead Trees/ Acre	1986 Cords[1] Dead/Ac	1986 Board Feet[2] Dead/Ac	1986 Cubic Feet[3] Dead/Ac	1991 Dead Trees/ Acre	1991 Cords[1] Dead/Ac	1991 Board Feet[2] Dead/Ac	1991 Cubic Feet[3] Dead/Ac
	-- All Trees[4] --							
Light	23.9	0.4	41.2	167.3	51.5	0.8	60.0	292.2
Mod-Heavy	33.3	1.9	314.2	322.6	38.3	1.5	193.1	313.5
All	24.0	0.4	42.5	168.1	51.4	0.8	60.7	292.3
	-- Dominant/Codominant Trees --							
Light	3.8	0.3	37.1	58.9	7.0	0.6	47.2	76.3
Mod-Heavy	12.3	1.7	303.8	205.9	18.4	1.3	189.4	211.7
All	3.8	0.3	38.4	15.2	7.1	0.6	47.9	77.0

1. The sound volume of trees 4.0 inches dbh and greater, measured in four foot increments, to a top diameter of four inches (inside bark) based on 1986 tree heights, excluding sawlog volume.
2. For sawtimber quality logs at least 8 feet long and a minimum diameter (outside bark) of 10.0 inches for conifers, white ash, and white birch, and 12.0 inches for other hardwoods.
3. Net volume of trees 4.0 inches dbh and greater.
4. 1.0 inches dbh and greater.

Table 3. Percentage of dominant/codominant trees healthy, with moderate dieback, with severe dieback, or dead, by tree species in Vermont hardwood stands, 1986 and 1991.

Species	No. of trees per acre		Crown Condition Class[1] Healthy		Moderate Dieback		Severe Dieback		Dead	
Hardwoods	1986	1991	1986	1991	1986	1991	1986	1991	1986	1991
			Percent							
Sugar maple	30.3	28.2	81.0	90.81	15.0	5.96	3.5	0.78	0.5	2.45
Red maple	27.8	26.1	79.0	89.43	18.7	7.16	1.7	2.07	0.6	1.34
Yellow birch	18.6	13.5	69.9	79.70	10.8	10.52	11.8	0.00	7.5	9.78
American beech	14.0	12.1	54.5	78.55	32.9	15.68	11.0	2.31	1.6	3.47
Paper birch	7.7	9.0	87.5	95.91	4.7	4.09	1.7	0.00	6.1	0.00
Oak	5.4	5.1	80.6	87.43	17.8	12.38	0.6	0.00	1.0	0.20
White ash	3.9	4.1	86.3	82.04	10.0	4.61	1.9	3.88	1.8	9.47
Black Cherry	2.4	2.9	82.9	74.48	11.7	19.58	5.4	0.00	0.0	5.94
Basswood	1.3	1.5	95.0	97.93	5.0	2.07	0.0	0.00	0.0	0.00
American elm	0.9	0.6	47.8	35.48	9.7	0.00	8.3	0.00	34.2	64.52
Aspen	2.6	0.5	88.6	42.42	9.0	0.00	0.0	12.50	2.4	45.08
Hickory	1.0	1.2	99.9	100.00	0.1	0.00	0.0	0.00	0.03	0.00
Other Hardwoods	11.9	10.6	85.6	78.34	10.9	5.84	1.9	1.60	1.6	14.22
All hardwoods	127.8	117.5	77.3	85.09	15.7	7.86	4.6	1.45	2.4	5.13
Conifers										
Spruce	4.0	3.3	67.8	79.88	4.7	13.51	13.5	0.90	14.0	5.71
Balsam fir	3.6	4.2	88.6	89.93	0.9	0.00	0.0	0.00	10.5	10.07
Pine	1.3	1.1	97.9	100.00	2.1	0.0 0	0.0	0.00	0.0	0.00
Hemlock	2.5	2.0	94.9	98.51	3.6	1.49	0.0	0.00	1.5	0.00
Other conifers	0.2	0.3	97.4	100.00	2.2	0.00	0.0	0.00	0.4	0.00
All conifers	11.6	10.9	83.9	89.76	3.0	4.66	4.7	0.27	8.4	9.41
All Species	139.5	128.5	77.8	85.6	14.6	7.6	4.7	1.4	2.9	5.5

1. Healthy = 0-10% crown dieback; moderate dieback = 11-50% crown dieback;severe dieback = more than 50% crown dieback; dead = all standing dead trees except snags.

QUALITY ASSURANCE AND CONTROL

Remeasurement of randomly selected points by different crews to determine variability in crown dieback and transparency ratings produced acceptable data quality results similar to those from other forest health monitoring programs (North American Sugar Maple Decline Project and National Forest Health Monitoring Program, 1990). Ninety-five percent of the crown dieback remeasurements and 91 percent of the crown transparency measurements fell within ±10 percent of the original measurements.❑

TREE CONDITION BY SPECIES

Healthy Trees

Nearly all species of trees in Vermont hardwood stands increased in percentage of living trees with healthy crowns between 1986 and 1991. This was particularly true for birch, beech and maple (Figure 5, Table 3). The dramatic improvement in beech crown conditions may be partially due to a decrease in oystershell scale populations. This insect caused beech twig and branch dieback in the mid-1980's when populations were at peak levels.

Crown condition improvement for sugar maple is similar to that reported for the North American Sugar Maple Decline Project (NAMP) based on plots throughout North America from Wisconsin and Ontario to New England and Nova Scotia (Millers et al. 1992).

This project reported that 4.1 percent of upper canopy sugar maples in forest stands not tapped for maple sap had crown dieback in excess of 15 percent in 1990 compared to 7.3 percent in 1988. Unpublished 1991 data from the NAMP survey for Vermont shows that 5 percent of the sugar maples in untapped stands exceeded 15 percent crown dieback. Our data, when recalculated for comparison with the NAMP data, shows that 4.6 percent of upper canopy sugar maples had more than 15 percent dieback (95.4% healthy) in 1991.

The total number of dominant/codominant trees on a per acre basis shows a slight expected drop as some trees die and our stands mature, but the number of healthy trees per acre (T/A) increased for the majority of hardwood trees (Appendix E). Only yellow birch (-1.1 T/A), white ash (-0.8 T/A), oak (-0.1 T/A), elm (-0.2 T/A), and aspen (-1.3 T/A) had fewer healthy trees per acre in 1991 than in 1986.

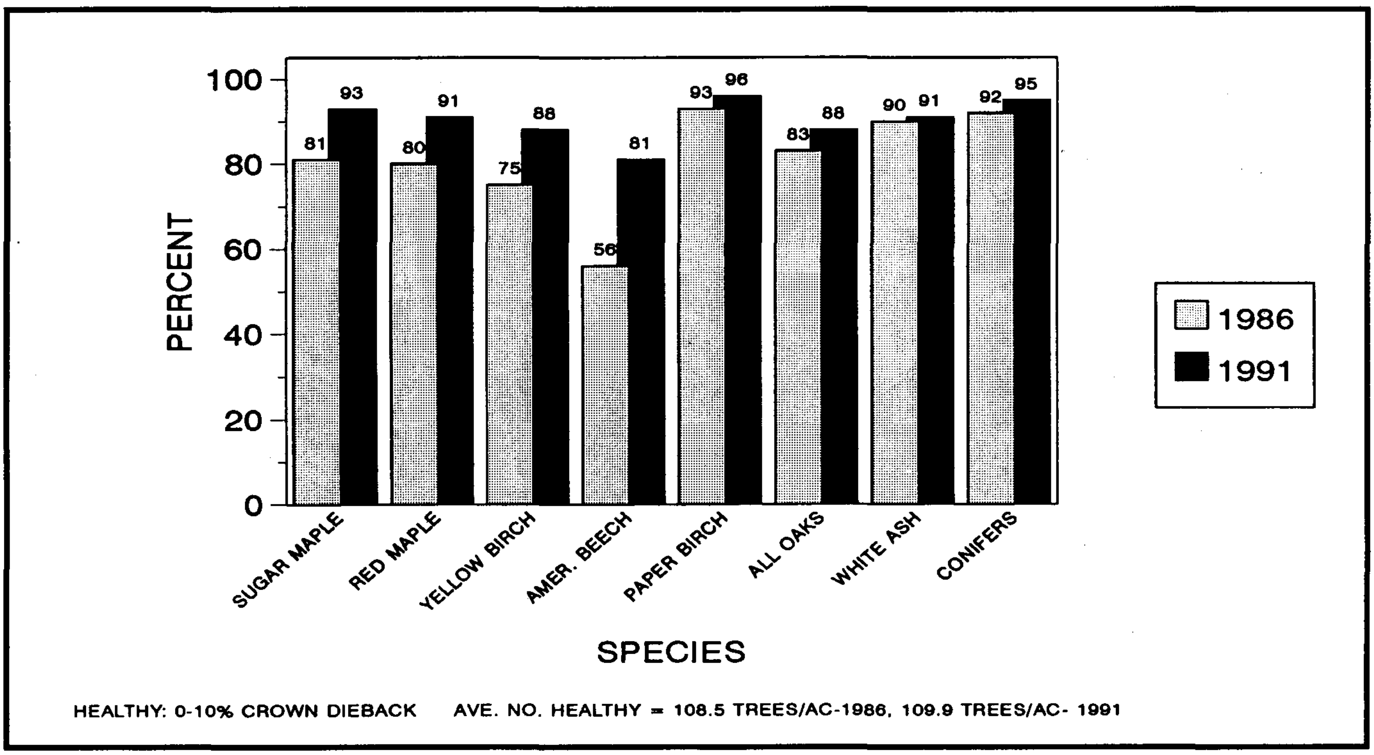

Figure 5. Percent of living dominant/codominant trees healthy by species, in Vermont hardwood stands in 1991 compared to 1986.

Dead Trees

Most tree species showed a small increase in the percentage of trees dead (Figure 6). Dead white ash trees increased more than most other species, from 1.8% in 1986 to 9.5% in 1991. This is probably because more than half the ash trees ground surveyed are located in a few Champlain Valley plots where ash yellows disease is prevalent.

Percentage of dead elms doubled in the five years, from 34.2% to 64.5%. This is probably the result of Dutch elm disease. Aspen increased from 2.4 percent dead to 45.1 percent dead (Table 3). Aspen is a short-lived, shade-intolerant species and such losses should be expected as competition from more tolerant species becomes excessive in maturing hardwood stands.❑

CROWN TRANSPARENCIES

Crown transparency ratings varied by tree species (Figure 7). Since 1991 was the first year these ratings were taken, comparisons to 1986 cannot be made. Except for black cherry, with an average transparency 1.5 percent higher than the New England average, all ratings were consistently higher (range of 0.3% - 4.4%) than those from the National Forest Health monitoring Program for all of New England in 1991 (A.J.R. Gillespie, personal communication).

This indicates that Vermont trees may have had denser crowns compared to New England as a region. Field crews involved in the Vermont ground survey report that most tree species in 1991 had the densest crowns that have been observed in recent years. These ratings might then reflect optimum transparency ratings by tree species for our hardwood stands and could establish an excellent transparency baseline for future surveys.❑

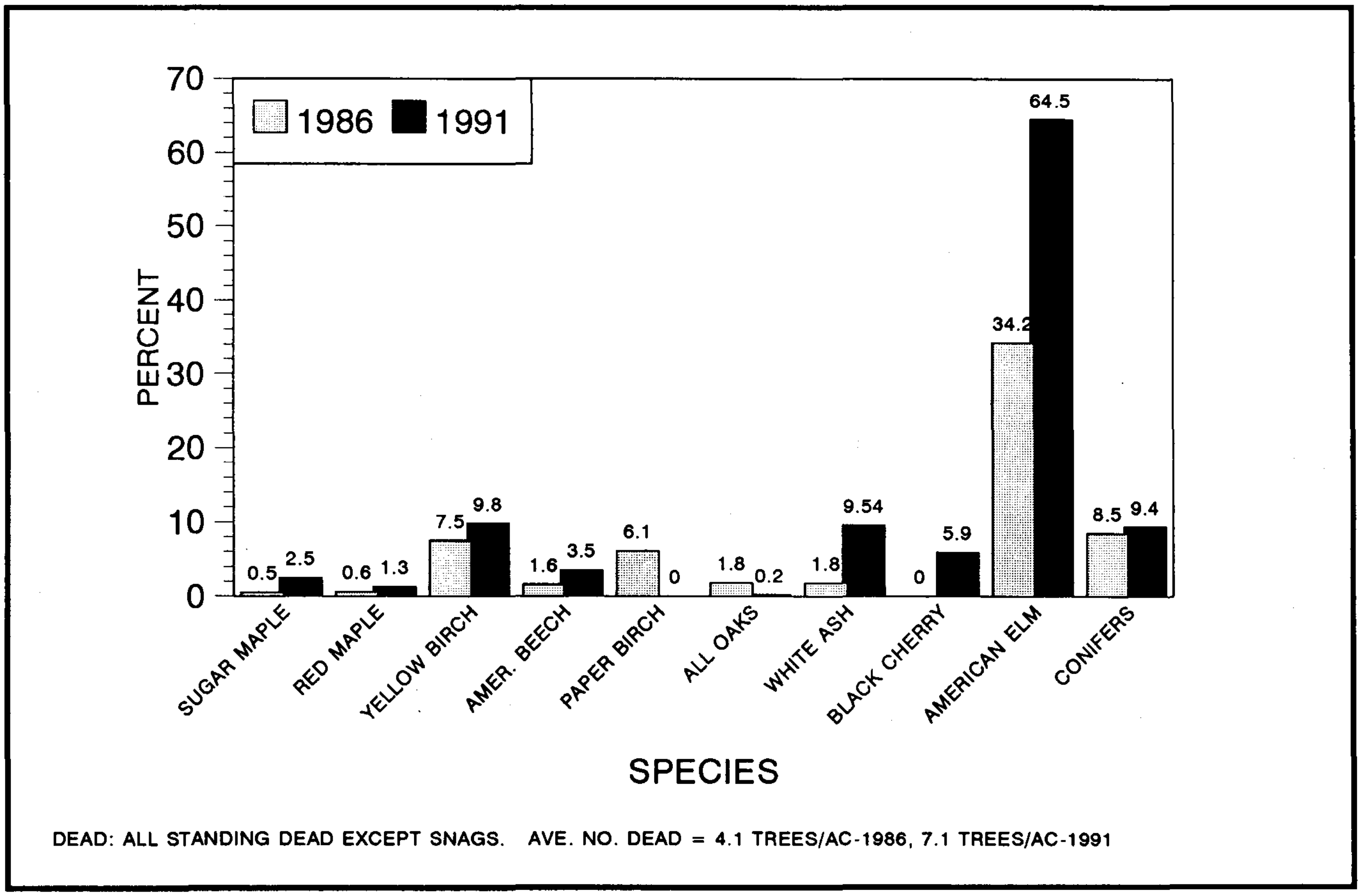

Figure 6. Percent of dominant/codominant trees dead, by species, in Vermont hardwood stands in 1991 compared to 1986.

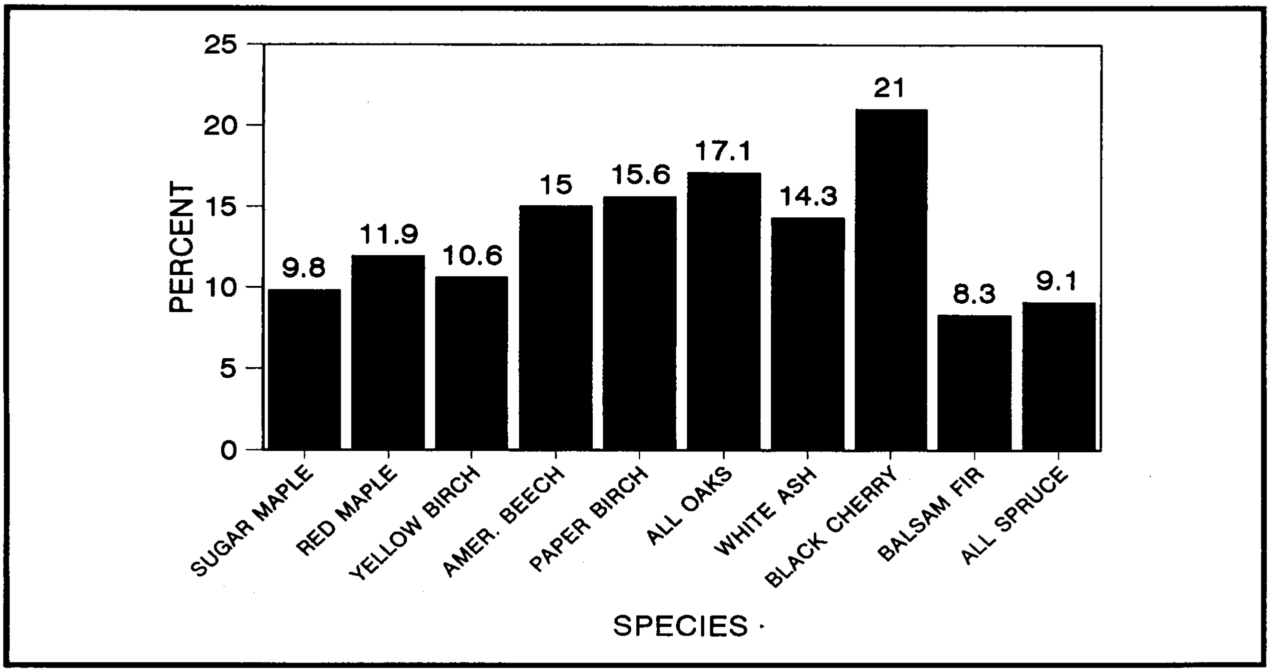

Figure 7. Average crown transparency ratings, by species, for dominant/codominant trees in Vermont hardwood stands in 1991.

ABILITY OF TREES TO RECOVER FOLLOWING DIEBACK

More than half (63%) of the upper canopy position trees with moderate dieback (11-50%) in 1986 had healthy crowns by 1991 (Figure 8). Only 13% died and 4% had severe dieback in 1991. An additional 18% remained in the moderate dieback category and could either continue declining or recover to a healthy condition in the future.

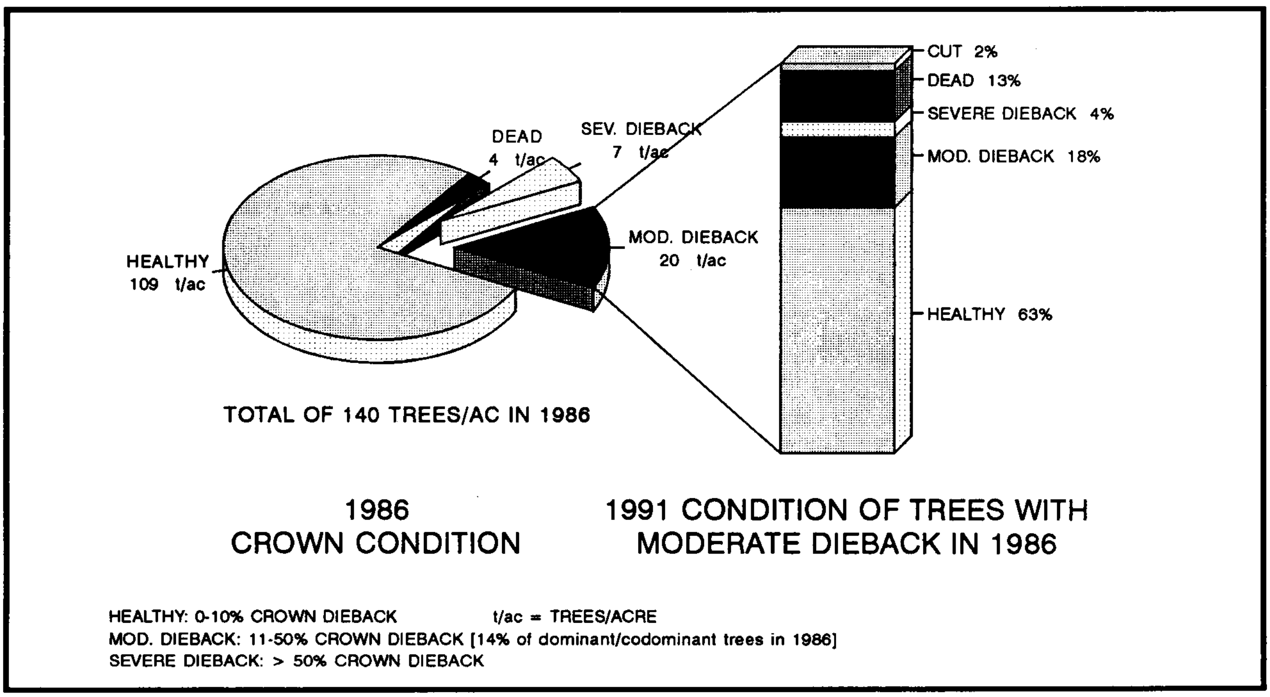

Figure 8. Condition of all dominant/codominant trees in 1991 that had moderate dieback in 1986.

For most of the more common hardwood species in upper canopy positions rated as healthy in 1986, at least 90% remained healthy in 1991 (Figure 9). Yellow birch was a little poorer in its ability to remain healthy.

The reasons for this are unclear but it may relate to the fact that it is a shallow-rooted species that is more sensitive to reduced moisture, small increases in soil temperature and winter freezing injury to roots than the other species. It may be responding to continued short-term climatic factors such as moderate drought conditions in the summer of 1988 and frozen soil due to little snow in the winter of 1988-89.

In 1983, mortality had reached 3.6 percent and continued to increase thereafter, to 9.7 percent in 1991 (Loranger 1992). Paper birch was less able to recover than the other species once dieback exceeded 10%. All of the paper birch trees and over 90% of the yellow birches with over 75% crown dieback in 1986 were dead in 1991 compared to 67% or fewer for sugar maples, red maples and beech (Appendix F).

Sugar maple showed the best ability to recover following severe dieback. Most sugar and red maples recovered from crown dieback up to 50%. Beyond that, red maple was much poorer at recoverability.

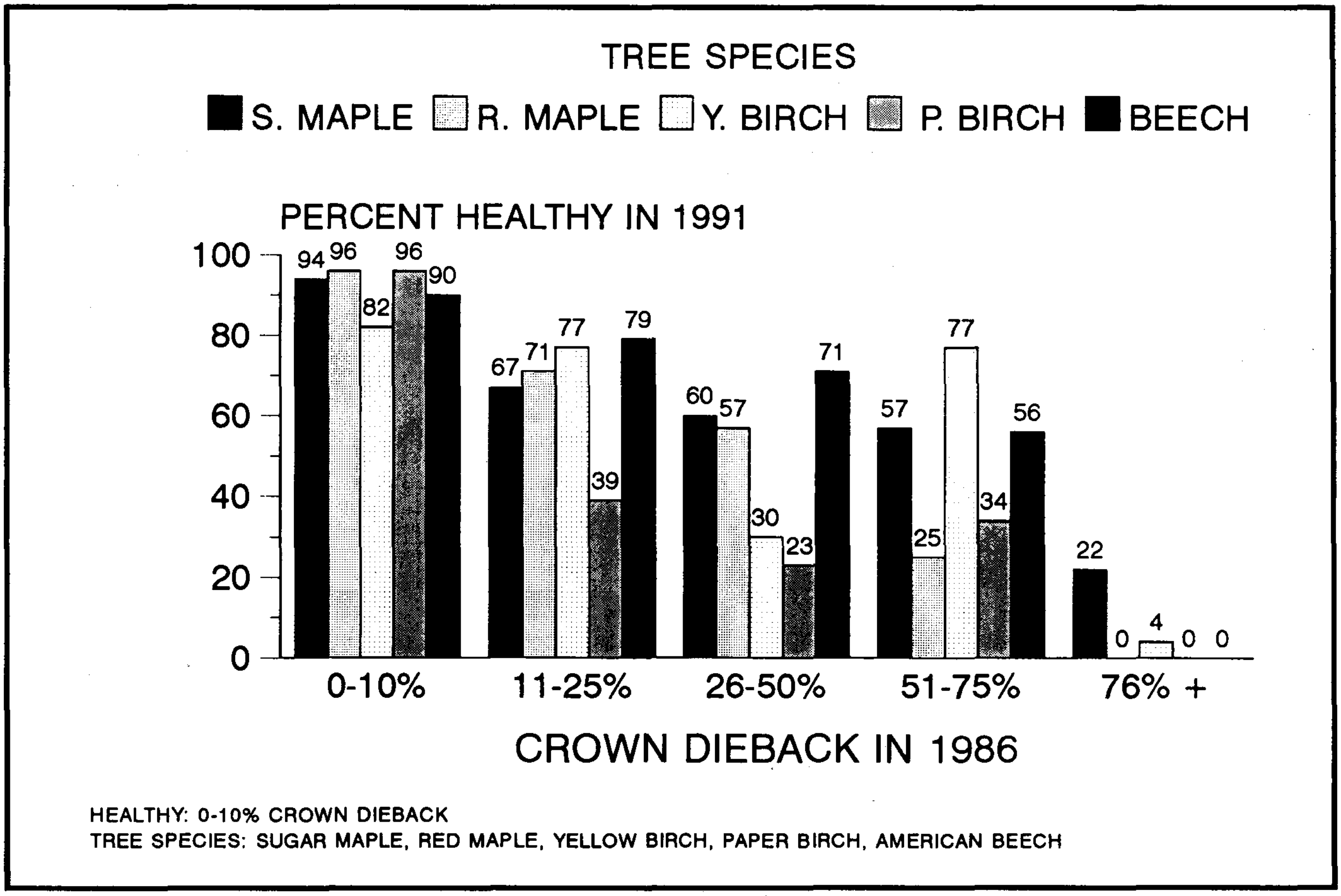

Figure 9. Percent of several dominant/codominant hardwood species in various crown dieback classes in 1986, that were rated as healthy in 1991.

Once dieback was initiated, yellow birch had a greater tendency to die than other tolerant hardwood species (Appendix F). This again, may be related to root injury. A survey of yellow birch plots established in 3 Essex County, Vermont, sites showed that tree mortality was only 0.3 percent in 1981, the first year following the cold, open winter of 1980-81.

Once dieback exceeded 75%, sugar maple was the only species that showed much recovery within five years.

Surprisingly, 22% of the sugar maples with over 75% dieback in 1986, were rated as healthy in 1991, although crowns of these survivors may have been smaller due to a loss of branches that were dead in 1986.❑

♦ANNUAL LOSSES

The annual mortality rate for all dominant/codominant trees in hardwood stands for this five-year period was 1.6% (Appendix D). Yellow birch and American beech losses were above average, at 4.0 and 3.5 percent, respectively. Beech Bark Disease continues to be a major cause of beech mortality. Sugar maple, red maple, and paper birch each lost fewer than one percent of the upper canopy position trees per year.❑

♦POSSIBLE REASONS FOR IMPROVED TREE CONDITION

Improvements in crown condition may be related to more favorable weather conditions between 1986 and 1991 and less insect damage compared to the 10 years preceding 1986. Between 1978 and 1982 when most dieback recorded in 1986 appeared to be initiated, growing season temperatures were generally above average and annual precipitation was below average in Vermont (Ludlum, 1985). This included a cold, snow-less winter in 1980-81 which may have affected shallow-rooted trees such as yellow birch (Clark and Barter 1958, Pomerleau 1991). In contrast, precipitation was near or above normal for most of the years from 1986 to 1991 (except for moderate drought in 1988), and there were no cold, open winters, although 1988-89 was open, but had normal temperatures. The especially wet years of 1989 and 1990 probably contributed to 1991 tree condition. According to data from the National Oceanic and Atmospheric Administration, annual precipitation for all stations in Vermont averaged about 4 inches above normal in 1989 and 13 inches above normal in 1990. Late spring frosts have occurred since 1986 but none have been as damaging to forest trees as the June 1980 frost (Appendix A). The death of many trees that were unhealthy in 1986 also contributed to improved tree health in 1991.

Defoliation from forest tent caterpillar and saddled prominent, the two most serious pests of sugar maple between 1976 and 1982, has not since been detected. A gypsy moth outbreak occurred from 1989 to 1991, but it was shorter in duration and less severe than the previous outbreak. The wetter years during the most recent outbreak led to a disease epidemic among the insects and presumably contributed to tree recovery following defoliation.

Pear thrips defoliated over 500,000 acres of sugar maple between 1987 and 1990, but this is an early-season defoliator and trees recovered well. Allen and Barnett (1991) evaluated data from North American Sugar Maple Decline Project study sites in Vermont and Massachusetts and found that sugar maple crown condition improved significantly one year after heavy thrips defoliation. Autumn snow storms in 1987 and 1990 caused much limb and tree breakage that contributed to the tree mortality observed in 1991. This could affect the long-term health of damaged surviving trees but was not a factor in the crown condition ratings.❑

♦CONCLUSIONS

This survey shows that overall, our hardwood forests are in good condition, with definite improvement since 1985. No widespread decline was detected and nearly 86 percent of all trees in upper canopy positions were healthy (less than 10% crown dieback) in 1991 compared to 78 percent in 1986. For the predominant hardwood species, over 88 percent had healthy tree crowns in 1991 except beech, which improved from 56 percent to 81 percent healthy.

The number of dead trees increased (2.9% to 5.5% standing dead) during the five years, mainly due to a progression of dieback on some of the trees that were unhealthy in 1986. Over 50 percent of the trees rated as severely declining in 1986 were dead in 1991. The deaths of these trees was probably triggered by stresses in the early 1980's. Improvements in crown condition of the surviving trees may be related to decreased insect damage and recent years with above average precipitation.❑

♦RECOMMENDATIONS

Evaluation of these trees on a five-year basis seems satisfactory for determining trends over time. This is a reasonable goal for future monitoring of this type as long as documentation of annual fluctuations and stressors affecting individual trees is not essential. We should continue to adopt any national forest health monitoring standards that are widely accepted and improve on our ability to describe tree conditions.❑

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APPENDIX A

Table 4. Major insects, diseases, and noninfectious agents detected as causing defoliation or other damage to hardwood forests in Vermont, beginning in 1970.[1]

Agent	Years(s)	Primary Hosts	Acres Mapped[2]	Remarks
Gypsy Moth	1976-82	Oaks	179,800	Mortality observed acres not mapped
	1989-91	Oaks	86,000	No mortality observed
Forest Tent Caterpillar	1976-82	Sugar Maple White ash	650,600	33,500 acres of mod-heavy mortality mapped
Saddled Prominent	1979-81	Sugar Maple Beech	102,700	2,300 acres of mod-heavy mortality mapped
Maple Leaf Cutter	1972-83	Sugar Maple	286,650	Dieback but no mortality observed
Frost	1980	Sugar Maple Other hardwoods	124,500	Heavy localized mortality, particularly in areas infested by forest tent caterpillars
Pear Thrips	1987-90	Sugar Maple	523,700	Dieback but no mortality observed
Ice/Snow	1987	All	---	October storm caused heaviest tree & limb breakage in southern VT
Ice/Snow	1990	All	---	November storm caused heaviest tree & limb breakage in northern VT

1. From Forest insect and disease conditions in Vermont, annual reports from 1970 to 1991. Vermont Department of Forests, Parks and Recreation, Waterbury, VT

2. Total cumulative acres mapped during annual aerial surveys.

PLOT DATA

Stand Geography		Outcropping or Roads	Drainage
1) hillside	5) plateau	1) present	1) poor
2) rolling	6) cove	2) absent	2) well
3) swamp	7) flat		3) excessive
4) mtn. top	8) bench		

Crown Closure	Logging History	Defol.	
1) <25%	1) no evidence	1) none	5) MLC
2) 25-74%	2) recent-slash	2) GM	6) frost
3) >75%	3) recent-stumps	3) FTC	7) other
	4) old-stumps	4) SP	

VERMONT HARDWOOD DIEBACK AND MORTALITY SURVEY

1 PHOTO POINT NO. ________ 2 PHOTO FRAME NO. ________ 3 CELL NO. ________ 4 CREW ________

5 LANDOWNER ________ 6 FOREST TYPE ________ 7 DATE ________

8 TOWN ________ REMARKS ________

9	PLOT NO.	
10	ELEVATION (100$_s$ of feet)	
11	SLOPE (%)	
12	ASPECT (°Azimuth)	
13	DISTANCE TREE 1 TO CENTER (ft)	
14	BEARING-TREE 1 TO CENTER (°Az)	
15	STAND GEOGRAPHY	
16	OUTCROPPINGS	
	ACTUAL OR GREATER THAN →	
DEPTH TO 17	BEDROCK (inches)	18
19	HARDPAN (inches)	20
21	MOTTLES (inches)	22
23	DRAINAGE	
24	CROWN CLOSURE	
25	ROADS	
26	LOGGING HISTORY	
27	DEFOLIATION HISTORY	
SITE INDEX 28	TREE NO.	
29	SPECIES	
30	HEIGHT (feet)	
FOR PLOTS 3 & 5 31	AGE	
32	SITE QUALITY	

INDICATOR PLANTS	SPECIES 33	MILACRE PLOTS	REG. 34	NO. 35
	1	1		
	2	2		
	3	3		
	4	4		
	5	5		

Show landmarks, roads, bearings, distances, and North arrow

SKETCH MAP OF CELL LOCATION

☐ check if this would not make a good permanent plot.

Topographic Map No. ________

GROUND COVER

1) Adv.Com.Hdw> 3'
2) Any Com.Hdw.
3) conifer
4) raspberry
5) other woody
6) fern
7) grass
8) other

INDICATOR PLANTS

1) blue cohosh
2) wild ginger
3) wild leek
4) maidenhair fern
5) wild sarsaparilla
6) wild lily-of-the-valley
7) staghorn clubmoss
8) bracken fern
9) wintergreen
10) starflower
11) meadow-rue
12) false hellebore
13) ostrich fern
14) interrupted fern
15) cinnamon fern
16) royal fern
17) jewel weed

FOREST TYPES

11) aspen-w.birch
20) w.pine-r.oak-w.ash
25) s.maple-beech-y.birch
27) s.maple
108) r.maple
39) ash-elm-r.maple
54) r.oak-basswood-w.ash

APPENDIX B-2

SPECIES
1)s.maple
2)r.maple
3)striped maple
4)y.birch
5)white birch
6)gray birch
7)aspen
8)w.ash
9)beech
10)cherry
11)basswood
12)elm
13)hickory
14)r.oak
15)w.oak
16)butternut
17)ironwood
18)hemlock
19)w.pine
20)r.pine
21)fir
22)r.spruce
23)w.spruce
24)other hwd
25)other conifer

CROWN CLASS
1)dominant
2)codominant
3)intermediate
4)overtopped

TREE HISTORY
0)surviving
1)ingrowth
2)stump
3)recent dead
4)old dead
5)snag

DIEBACK/TRANS
00 0
05 1–5
10 6–10
15 11–15
: :
99 96–100

SYMPTOMS
1)scorch
2)chlorosis
3)small leaves
4)tattering
5)defoliation
6)off–color leaves
7)dead areas in leaves
8)dead leaves
9)fine twigs dead
10)branches dead
11)flagging
12)broken branches

LOCATION OF SYMPTOMS
1)upper 1/2
2)lower 1/2
3)side
4)whole tree

% OF CROWN AFFECTED
1) 1–100%
2)11–25%
3)26–50%
4)51–75%
5)>75%

CAUSAL AGENTS
1)logging
2)bird/anim.
3)other wounds or mech.
4)stem rot
5)canker
6)s.m.borer
7)beech bk. dis.
8)d.elm dis.
9)W.P.B.R.
10)leaf dis.
11)other dis.
12)ice/snow
13)wind
14)wet feet
15)lighting
16)tapping
17)oystershell scale
18)B.L.M.
19)MLC
20)thrips
21)frost
22)other insects
23)unknown other weather

PHOTO	CELL #	PLOT 9	TREE # 43	HIST 44	SP 45	DBH INCHES 46	CL 47	HEIGHT SAWLOGS 8' 48	HEIGHT PULP 4' 49	CROWN DIEBACK 50	CROWN TRANS 51	SYMP 1 52	LOC 53	% CROWL 54	CAUSAL AGENT 55	SYMP 2 56	LOC 57	% CROWL 58	CAUSAL AGENT 59	SYMP 3 60	LOC 61	% CROWL 62	CAUSAL AGENT 63	SYMP 4 64	LOC 65	% CROWL 66	CAUSAL AGENT 67	AGENT 1 68	AGENT 2 69	AGENT 3 70	AGENT 4 71	AGENT 5 72	REMARKS
C12	F02	5	1		14		2	0	20																								
C12	F02	5	2		14		2	8	8																								
C12	F02	5	3		19		1	24	20																								
C12	F02	5	4		14		2	0	0																								
C12	F02	5	5		14		2	8	12																								
C12	F02	5	6		14		2	0	32																								
C12	F02	5	7		14		2	0	0																								
C12	F02	5	8		19		1	16	20																								
C12	F02	5	9		24		4	0	0																								
C12	F02	5	10		14		2	0	16																								
C12	F02	5	11		17		4	0	0																								
C12	F02	5	12		14		3	0	16																								

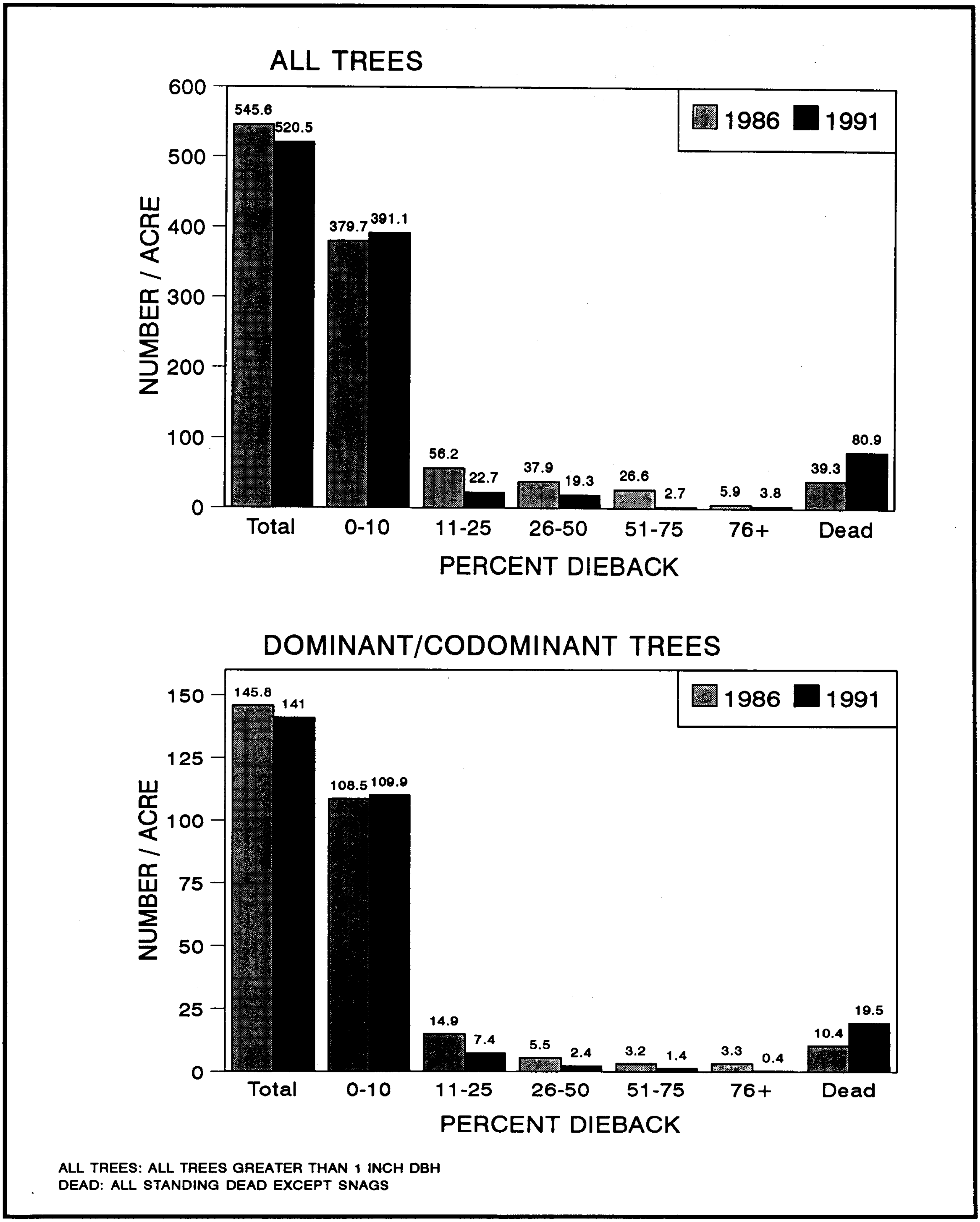


Figure 10. Number of trees per acre by crown dieback classes for all trees and dominant/codominant trees in Vermont hardwood stands in 1986 and 1991.

APPENDIX D

Volume of dead trees and all trees in 1986 and 1991.

Table 5A. Sawtimber volume/acre of all trees and dead trees ground surveyed within hardwood stands by photo interpretation mortality class - 1986 and 1991.

	1986 Sawtimber Volume[1] Board Feet/Acre				1991 Sawtimber Volume[1] Board Feet/Acre			
P.I. Mortality Class	**All**	**SE[2]**	**Dead**	**SE[2]**	**All**	**SE[2]**	**Dead**	**SE[2]**
Light	3656	365	41	17	3804	374	60	18
Mod-Heavy	2081	384	314	126	2144	388	193	92
All	3648	363	42	19	3796	372	61	18

1. For sawtimber quality logs at least 8 feet long and a minimum diameter outside bark of 10.0 inches for conifers, white ash, and white birch, and 12.0 inches for other hardwoods.

2. SE = standard error of the mean.

Table 5B. Cordwood volume/acre of all trees and dead trees ground surveyed within hardwood stands by photo interpretation mortality class - 1986 and 1991.

	1986 Cordwood Volume[1] Cords/Acre				1991 Cordwood Volume[1] Cords/Acre			
P.I. Mortality Class	**All**	**SE[2]**	**Dead**	**SE[2]**	**All**	**SE[2]**	**Dead**	**SE[2]**
Light	21.29	1.22	0.42	0.10	22.24	1.23	0.81	0.11
Mod-Heavy	14.91	1.49	1.91	0.52	15.87	1.54	1.50	0.37
All	21.26	1.21	0.43	0.12	22.21	1.22	0.81	0.11

1. The sound volume of trees 4.0 inches dbh and greater for logs at least 4 feet long, to a top diameter of 4 inches inside bark, based on 1986 tree heights.

2. SE = standard error of the mean.

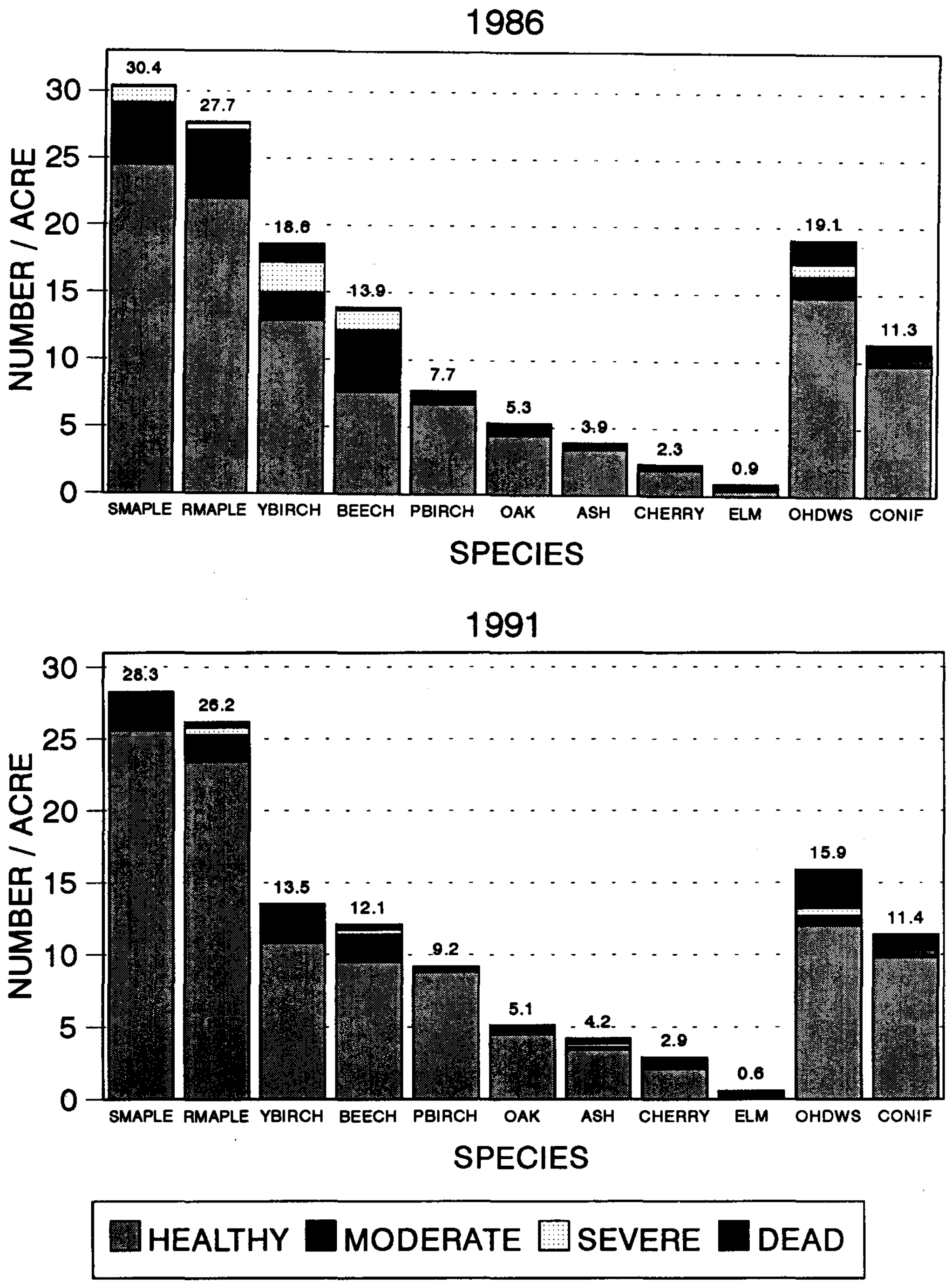
Table 5C. Cubic foot volume/acre of all trees and dead trees ground surveyed, within hardwood stands, by photo interpretation mortality class - 1986 and 1991.

	1986 Cubic Foot Volume[1] Cubic Feet/Acre				1991 Cubic Foot Volume[1] Cubic Feet/Acre			
P.I. Mortality Class	**All**	**SE[2]**	**Dead**	**SE[2]**	**All**	**SE[2]**	**Dead**	**SE[2]**
Light	4141	179	167	34	4416	191	292	49
Mod-Heavy	3431	263	323	70	3917	305	313	59
All	4137	178	168	39	4413	190	292	50

1. Estimated net volume of trees 4.0 inches dbh and greater.

2. SE = standard error of the mean.

APPENDIX E



HEALTHY: 0-10% CROWN DIEBACK, MODERATE: 11-50%, SEVERE: >50% CROWN DIEBACK SMAPLE=SUGAR MAPLE RMAPLE=RED MAPLE YBIRCH=YELLOW BIRCH BEECH=AMERICAN BEECH PBIRCH=PAPER BIRCH OAK=ALL OAKS ASH=WHITE ASH CHERRY=BLACK CHERRY ELM=AMERICAN ELM OHDWS=OTHER HARDWOODS CONIF=CONIFERS

Figure 11. Number of dominant/codominant trees per acre and crown condition of predominant species in Vermont hardwood stands in 1986 compared to 1991.

APPENDIX F

Table 6. Percent of dominant/codominant trees living in 1986 (by 1986 crown dieback classes) that were dead[1] in 1991, by species, in Vermont hardwood stands.

Percent Crown Dieback - 1986	Sugar Maple	Red Maple	Yellow Birch	Paper Birch	American Beech	All Species
	......................Percent of trees dead - 1991					....
0-10	0.90	0.22	5.50	0.65	16.31	4.04
11-25	25.94	3.50	11.76	0.00	6.81	7.96
26-50	11.67	12.50	68.42	0.62	16.90	29.20
51-75	20.83	22.73	4.55	0.00	73.35	17.88
76 +	66.67	62.50	91.51	100.00	16.67	83.50
All Classes	3.31	1.21	20.15	3.28	17.26	7.95
Annual Mortality	0.66	0.24	4.03	0.66	3.45	1.59

1. Dead = all dead trees (including those on the ground) that were living in 1986, except harvested trees.